CHARACTERISTICS OF FINITE GROUND COPLANAR WAVEGUIDE LUMPED ELEMENTS

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ABSTRACT

This paper presents the measured characteristics of lumped elements in coplanar waveguide with narrow width ground planes. It is shown for the first time that lumped elements may be placed in the ground planes of the Finite Ground Coplanar waveguide (FGC) to obtain enhanced electrical characteristics.

INTRODUCTION

Finite Ground Coplanar waveguide (FGC) is being used more extensively in microwave and millimeter-wave integrated circuits to increase the circuit density and eliminate the parasitic resonances that can be excited by conventional coplanar waveguide integrated circuits when they operate in a packaged environment [1,2]. Conventional coplanar waveguide (CPW) designs only use the center strip conductor to perform electrical functions including the integration of lumped elements. While these have been successful, they do not provide optimal circuit compactness.

Herein, a novel approach is considered where the ground planes are utilized in a similar manner as the center strip conductor of conventional CPW. When the ground plane width is narrow compared to the center strip width to create a three conductor transmission line as shown in Figure 1, the ground planes may be viewed as another current carrying strip and lumped elements can be implemented in them in the same way that they are implemented in the center strip. Thus, in this paper, FGC

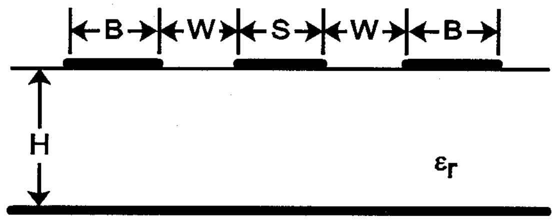

Figure 1: Finite Ground Coplanar (FGC) waveguide.

lines with equal width ground planes and center conductors are used, and measured characteristics of thin film resistors (TFR) and MIM capacitors placed in the center strip and the ground planes of the FGC as shown in Figures 2 and 3 respectively are presented.

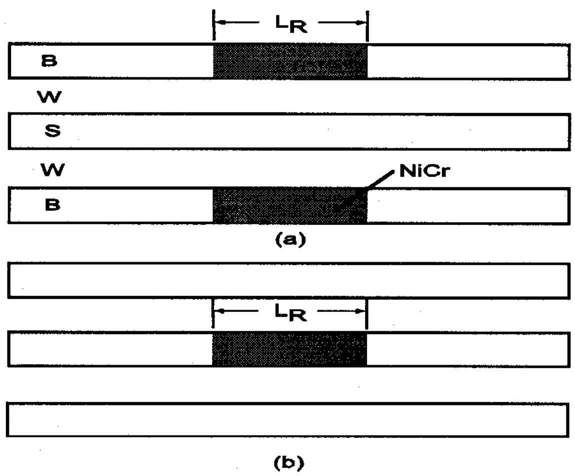

Figure 2: Schematic of thin film resistor in the (a) ground planes and (b) center conductor of FGC.

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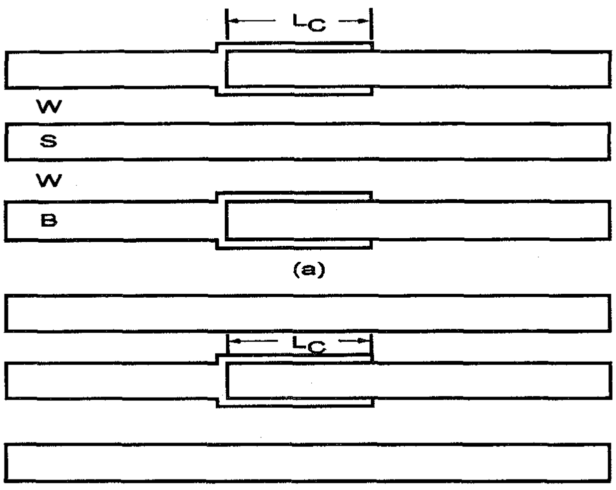

Figure 3: Schematic of MIM capacitor in the (a) ground planes and (b) center conductor of FGC.

MEASUREMENT PROCEDURE

Finite ground coplanar lines with $S=W=B=50$ μm are fabricated on high resistivity silicon, ρ>2500 Ω-cm and $\varepsilon_r=11.9$, wafers of 411 μm thickness. The metal patterns are defined through a liftoff process and consist of 1.3 μm of Au with a 0.02 μm adhesion layer. Electron beam evaporated NiCr of 0.07 μm thickness is used for the thin film resistors. The MIM capacitors consist of a first level metal Au layer, 0.2 μm Si_3N_4, and a 1.3 μm Au upper plate. The lower plate of the capacitor is 20 μm wider than the center strip and ground plane width while the upper plate has a width of 50 μm. Thus, the area of the capacitors is equal to S or B (50 μm) times the length of the upper plate, L_C, as shown in Figure 3.

The measurements are performed with an HP 8510C vector network analyzer and GGB Industries picoprobes. Calibration of the measurement system up to the reference planes of the lumped elements is accomplished with MULTICAL, a TRL calibration software available from NIST [3], and calibration standards fabricated on the wafer with the test circuits. To reduce random errors, the process of calibrating the system and measuring the device characteristics is repeated three times and the measured S-parameters averaged before any data analysis occurs. The measured S-parameters are then converted to Y-parameters from which the lumped element equivalent circuits are extracted.

RESULTS

We consider in this paper two different ways of implementing thin film resistors and MIM capacitors. To model the thin film resistors, a series RL circuit is assumed with a pair of equivalent shunt capacitors to ground as shown in Figure 4. The equivalent circuit resistance

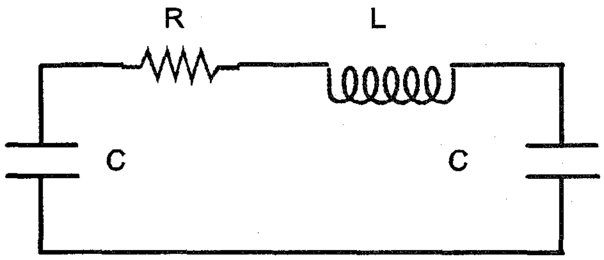

Figure 4: Equivalent circuit model for thin film resistor in FGC.

as a function of the resistor length is shown in Figure 5 where it is seen that the DC measured resistance of the resistor placed in the center strip is twice as large as the same length resistor placed in the ground planes, while the RF determined resistance of the center strip resistor is approximately three times larger than the ground resistor. It was found that the parasitic reactances are independent of the placement of the resistor which is interesting since the associated inductance is expected to vary the same as the resistance values.

The model of the MIM capacitor is shown in Figure 6 and its equivalent circuit element values as a function of the length L_C are shown in Figures 7 and 8. The capacitance C_{12} is approximately two and a half times larger when the capacitor is placed in the ground planes, while the parasitic shunt capacitances shown in Figure 8 are independent of the capacitor placement. In Figure 7, the self resonant frequency of the capacitors is also plotted. It is seen that for the same value of capacitance, the resonant frequency is higher when the capacitor is placed in the ground plane. Furthermore, if it is assumed that the resonance is due to a series inductance, it is found that the value of this parasitic inductance is dependent only on the length of the capacitor and not on its placement.

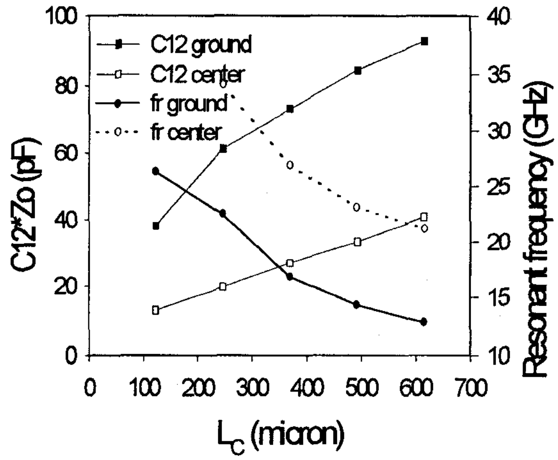

Figure 7: Series capacitance and self resonant frequency of MIM capacitor in center conductor and ground plane as a function of the capacitor length.

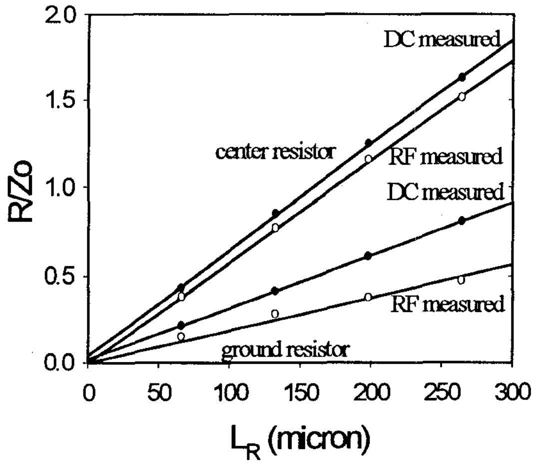

Figure 5: Resistance values of thin film resistor in center conductor and ground plane as a function of the resistor length.

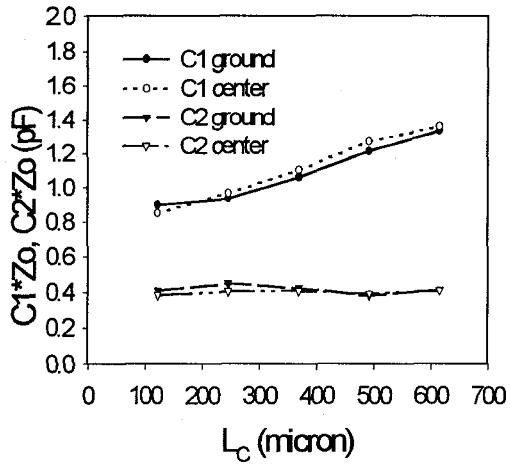

Figure 8: Shunt capacitance values of MIM capacitor placed in center conductor and ground plane as a function of the capacitor length.

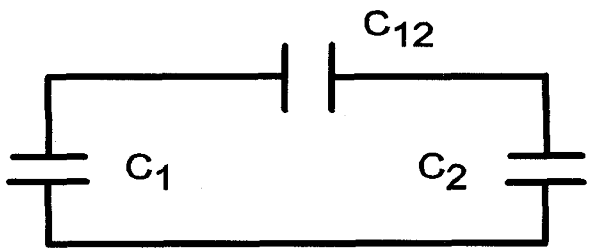

Figure 6: Equivalent circuit model for MIM capacitor in FGC.

OBSERVATIONS AND CONCLUSIONS

In this work, we have investigated the use of narrow width ground planes for the novel implementation of thin film resistors and MIM capacitors. The results indicate that lumped elements placed in the ground planes behave to a first order approximation as two elements in parallel, while the parasitic reactances associated with the resistor and capacitor are independent of their placement in the FGC line. Since it is desirable to reduce the dimensions of elements to permit denser circuit layouts, capacitors should be placed in the ground planes, especially for large blocking capacitors. Qualitative observations of the measured results do not indicate the presence of multimoding problems associated with the transmission line, although there is more variation in the deembedded Y-parameters as a function of frequency when the elements are placed in the ground planes. This may indicate the need for a more complicated circuit model to account for parasitic elements not included in the simple models presented here.

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